Fabrication approaches for plasmon-improved photovoltaic cells

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Fabrication approaches for plasmon-improved photovoltaic cells

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Abstract-During this talk we will present various fabrication approaches to improve the performance of photovoltaic (PV) cells by using metallic nanoparticles in order to generate photocurrent below the bandgap. This effect is possible due to the generation of surface plasmon polaritons (SPPs) in optimized nanoparticles.

Small metal nanoparticles(NPs) may, in certain conditions, absorb the incoming photons and generate SPPs that add to the photocurrent generated within a PV cell [1-3]. Since the frequency of the absorbed light is defined by the particle size, shape and placement, it can be adjusted such that it lies below the bandgap of the photovoltaic cell material. This way the light that would otherwise be lost is used for increasing the PV cell efficiency [4, 5].

Our initial choice of metal was Au. Although Au is not the best metal available for SPP propagation, it has the advantage of being a noble metal thus its properties are not changing in time as for example the ones of Ag do. Still, the low surface adhesion of Au on GaAs or Si, the materials of choice for PV cells, introduces an extra step in the fabrication process. Thus, before Au deposition, a thin layer of Ti must be used. We believe that this thin Ti layer may limit the Au performance to a point where the increase in absorption is hardly observable. During the talk we will present several attempts where the Au nanoparticles, although similar in shape and size and matching the dimensions of the simulated ones, show no absorption increase (see figure 1).

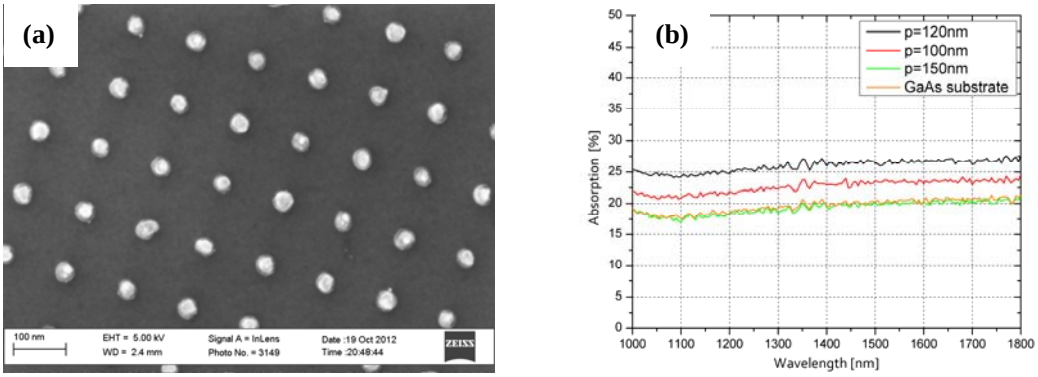

Figure 1. (a) SEM image of typical Au nanoparticles. The period of the particles is 100nm while their size is of 35nm. (b) absorption graphs for Au nanoparticles with different periodicities. Although measured in a big frequency range, the nanoparticles show no resonant absorption.

Due to these difficulties in utilizing Au NPs, as well as better behavior of the Ag particles [6] we decided to switch to Ag ones. The change in materials came with new challenges. On one side, the Ag is less stable than Au thus the deposition process needs to be altered. Also, the dimensions of the particles are now at the limit of the electron beam lithography(EBL) technique, thus making them more expensive and difficult to fabricate. Due to

these two aspects we decided to try, apart from the EBL technique, electroless deposition of Ag nanoparticles on the desired substrate. This deposition method has the advantage of being cheap, large scale and the particle size can be accurately controlled. Also, the stability of the grown particles is much higher than the one of the evaporated ones. The disadvantage of this technique is brought by its sensitivity to the NP growth to the surface chemistry. Thus, the same recipe will give completely different results in terms of crystal size and shape if used for Si or GaAs substrates (see figure 2). Thus, although the filling fraction is of about 46% for both cases, in the Si one the average particle size is about 8 times smaller than in the GaAs one. During the talk we will present various approaches for controlling the growth on these substrates.

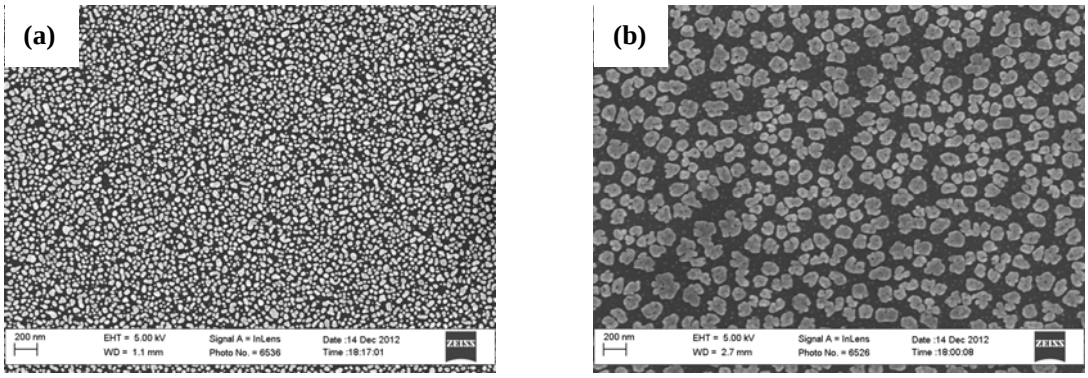

Figure 2. Difference in the growth of the nanoparticles on Si(a) and GaAs(b). The two samples were fabricated in the same time and using the same recipe thus the only varying parameter is the surface property one.

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